

12-08-99

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Case Docket No. PHN 17,446

THE COMMISSIONER OF PATENTS AND TRADEMARKS, Washington, D.C. 20231

Enclosed for filing is the patent application of Inventor(s):
STEFANO OLIVIERI

For: MOTION VECTOR ESTIMATION

ENCLOSED ARE:

- ☒ Associate Power of Attorney;
☒ Information Disclosure Statement, Form PTO-1449 and copies of documents listed therein;
☐ Preliminary Amendment;
☒ Specification (12 Pages of Specification, Claims, & Abstract);
☒ Declaration and Power of Attorney:
 (1 Page of a ☐ fully executed ☒ unsigned Declaration);
☒ Drawing (1 sheet of ☐ informal ☒ formal sheets);
☒ Certified copy of EUROPEAN application Serial No. 98204149.3;
☒ Other: AUTHORIZATION PURSUANT TO 37 CFR 1.136(a)(3);
☒ Other: CITATION OF RELATED CASES;
☐ Assignment to

FEE COMPUTATION

CLAIMS AS FILED				
FOR	NUMBER FILED	NUMBER EXTRA	RATE	BASIC FEE - 760.00
Total Claims	2 - 20 =	0	X \$18 =	0.00
Independent Claims	1 - 3 =	0	X \$78 =	0.00
Multiple Dependent Claims, if any			\$260 =	0.00
TOTAL FILING FEE				\$760.00

Please charge Deposit Account No. 14-1270 in the amount of the total filing fee indicated above, plus any deficiencies. The Commissioner is also hereby authorized to charge any other fees which may be required, except the issue fee, or credit any overpayment to Account No. 14-1270.

☐ Amend the specification by inserting before the first line the sentence: --This is a continuation-in-part of application Serial No. , filed .--.

CERTIFICATE OF EXPRESS MAILING

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 I hereby certify that this paper and/or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Typed Name

Signature



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 JCT14 U.S. PTO

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 09/455662

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of

Atty. Docket

STEFANO OLIVIERI

PHN 17,446

Serial No.

Group Art Unit

Filed: CONCURRENTLY

Ex.

MOTION VECTOR ESTIMATION

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231

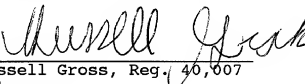
CITATION OF RELATED CASES

Sir:

Attached is a report which was made by the assignee of the above-identified patent application.

The United States patent applications and issued patents identified in this report may be relevant to the examination of the above-identified patent application inasmuch as they have been identified by an automated search of the assignee's patent portfolio files as having common inventors with and/or subject matter which is classified by the assignee in the same technological field as the above-identified patent application. However, citation of this report is neither an admission that any document noted therein is prior art to the above-identified patent application nor a waiver of the confidential status of any listed patent application under 35 U.S.C. 122.

Respectfully submitted,

By 
Russell Gross, Reg. 40,007
Attorney
(914) 333-9631

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JCE25 U.S. PRO
09/15/62
12/07/99

Related Cases/Technology Report for PHN 17446

OLIVIERI, STEFANO

Docket No.: PHN 17446

Attorney: UNASSIGNED

Patent No.:

Serial No.:

OS Codes : DV 1100

TV 4400

Title : MOTION VECTOR ESTIMATION.

Related Technology

KRISHNAMACHARI, S.

Docket No.: PHA 23823

Attorney: GATHMAN

Patent No.:

Serial No.: 09/433507

OS Codes : DV 1100

Title : IMPROVE3D CASCADED COMPRESSION METHOD AND SYSTEM
VIDEO AND IMAGES.

RADHA, HAYDER

Docket No.: PHA 23852P

Attorney: GATHMAN

VAN DER SCHAAR, MIHAELA

Patent No.:

Serial No.:

CHEN, YINGWEI

OS Codes : DV 1100

Title : HYBRID TEMPORAL-SNR FINE-GRANULAR SCALABILITY

BOISSY, JEAN-CHRISTOPHE

Docket No.: PHF 98615

Attorney: GROSS

HEPLIN, VALERIE

Patent No.:

Serial No.:

OS Codes : DV 1100

Title : SIGNAL PROCESSING.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of

Atty. Docket

STEFANO OLIVIERI

PHN 17,446

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MOTION VECTOR ESTIMATION

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Washington, D.C. 20231



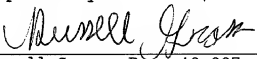
AUTHORIZATION PURSUANT TO 37 CFR §1.136(a)(3)
AND TO CHARGE DEPOSIT ACCOUNT

Sir:

The Commissioner is hereby requested and authorized to treat any concurrent or future reply in this application requiring a petition for extension of time for its timely submission, as incorporating a petition for extension of time for the appropriate length of time.

Please charge any additional fees which may now or in the future be required in this application, including extension of time fees, but excluding the issue fee unless explicitly requested to do so, and credit any overpayment, to Deposit Account No. 14-1270.

Respectfully submitted,

By 
Russell Gross, Reg. 40,007
Attorney
914) 333-9631

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of

Atty. Docket

STEFANO OLIVIERI

PHN 17,446

Serial No.

Group Art Unit

Filed: CONCURRENTLY

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MOTION VECTOR ESTIMATION

Honorable Commissioner of Patents and Trademarks
Washington, D.C. 20231



APPOINTMENT OF ASSOCIATES

Sir:

The undersigned Attorney of Record hereby revokes all prior appointments (if any) of Associate Attorney(s) or Agent(s) in the above-captioned case and appoints:

RUSSELL GROSS

(Registration No. 40,007)

c/o U.S. PHILIPS CORPORATION, Intellectual Property Department, 580 White Plains Road, Tarrytown, New York 10591, his Associate Attorney(s)/Agent(s) with all the usual powers to prosecute the above-identified application and any division or continuation thereof, to make alterations and amendments therein, and to transact all business in the Patent and Trademark Office connected therewith.

ALL CORRESPONDENCE CONCERNING THIS APPLICATION AND THE LETTERS PATENT WHEN GRANTED SHOULD BE ADDRESSED TO THE UNDERSIGNED ATTORNEY OF RECORD.

Respectfully,

Algy Tamoshunas, Reg. 27,677
Attorney of Record

Dated at Tarrytown, New York
this 6TH day of DECEMBER, 1999.

Motion vector estimation.

The invention relates to a method and device for motion vector estimation.

The H.263 standard for low bit-rate video-conferencing [1]-[2] is based on a video compression procedure that exploits the high degree of spatial and temporal correlation in natural video sequences. The hybrid DPCM/DCT coding removes temporal redundancy using inter-frame motion compensation. The H.263 coding standard defines the techniques to be used and the syntax of the bit-stream. There are some degrees of freedom in the design of the encoder. The standard puts no constraints about important processing stages such as motion estimation, adaptive scalar quantization, and bit-rate control.

As far as the motion estimation part is concerned, block-matching motion estimation algorithms are usually adopted to estimate the motion field between the current frame to be coded and the previous decoded frame. The objective of motion field estimation for typical hybrid coding schemes is to achieve high motion-compensation performance; however, the evaluation of a large number of candidate vectors for each block can create a huge burden. To save computational effort, a clever search strategy can prevent that all possible vectors need to be checked.

In order to estimate the motion field related to the sequence to be coded, it is possible to use the 3-Dimensional Recursive Search block matching algorithm presented in [3] and [4]. Unlike the more expensive full-search block matchers that estimate all the possible displacements within a search area, this algorithm only investigates a very limited number of possible displacements. By carefully choosing the candidate vectors, a high performance can be achieved, approaching almost true motion, with a low complexity design.

The 3D-RS algorithm stimulates coherency of the vector field by employing recursion. However, in H.263 video coding context, the extremely smooth estimated motion field impairs the efficiency of the resulting displacement-compensated image prediction. Thus, a compromise must be found between minimizing the entropy of the displacement vectors and minimizing the displaced frame difference between temporally adjacent frames.

It is, inter alia, an object of the invention to provide an improved motion vector estimation. To this end, the invention provides a motion vector estimation method and device as defined in the independent claims. Advantageous embodiments are defined in the dependent claims.

5 In a method of recursive motion vector estimation according to the present invention, a plurality of candidate vectors is generated from stored vectors, one of these candidate vectors is selected to generate a selected vector, a plurality of test vectors is generated from the selected vector, one of the test vectors is selected to generate an output vector, and the output vector is stored.

10 These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

The drawing shows a block diagram of an enhanced three-dimensional recursive search circuit in accordance with the present invention.

15 The invention proposes the design of an enhanced 3D-RS motion estimation algorithm that significantly improves the performance in terms of coding efficiency and leads to very good perceptual quality of the coded pictures, while keeping reasonably low the increase of the computational load.

20 The organization of the remainder of this document is as follows. First, the motion estimation part of the video codec is briefly summarized. Thereafter, the design of the 3D-RS motion estimation algorithm is introduced. Finally, the proposed Enhanced 3D-RS algorithm is described.

25 Encoding strategy: motion estimation techniques.

Motion estimation is part of the inter-frame coding principle. Macro-blocks of the current frame are matched to the frame previously coded. In other words, for a specific position, possibly on slightly translated co-ordinates in the previous frame the best match is found. The underlying necessary translation giving this best match is referred to as the displacement vector. The difference image between the current block and the translated block
30 in the previous frame is referred to as the motion compensated signal. This signal is forwarded to the coding part, in combination with the displacement vector.

In block-matching motion estimation algorithms, a displacement vector, or motion vector $\vec{d}(\vec{b}_c, t)$, is assigned to the center $\vec{b}_c = (x_c, y_c)^T$ of a block of pixels $B(\vec{b}_c)$ in the current image $I(\vec{x}, t)$, where tr means transpose. The assignment is done if $B(\vec{b}_c)$ matches a similar block within a search area $SA(\vec{b}_c)$, also centered at \vec{b}_c , but in the previous image $I(\vec{x}, t - T)$. The similar block has a center that is shifted with respect to \vec{b}_c , over the motion vector $\vec{d}(\vec{b}_c, t)$. To find $\vec{d}(\vec{b}_c, t)$, a number of candidate vectors \vec{C} are evaluated applying an error measure $e(\vec{C}, \vec{b}_c, t)$ to quantify block similarity.

The pixels in the block $B(\vec{b}_c)$ have the following positions:

$$(x_c - X/2 \leq x \leq x_c + X/2)$$

$$(y_c - Y/2 \leq y \leq y_c + Y/2)$$

with X and Y the block width and block height respectively, and $\vec{x} = (x, y)^T$ the spatial position in the image.

Although the cost function itself can be rather straightforward and simple to implement, the high repetition factor for this calculation creates a huge burden. This occurs if many candidate vectors are evaluated, i.e. if large search areas are considered. To save computational effort in block-matching motion estimation algorithms, a clever search strategy has to be designed, preventing that all possible vectors need to be checked.

3-Dimensional Recursive Search

The 3-Dimensional Recursive Search block matching algorithm, presented in [3] and [4], only investigates a very limited number of possible displacements. By carefully choosing the candidate vectors, a high performance can be achieved, approaching almost true motion, with a low complexity design. Its attractiveness was earlier proven in an IC for SD-TV consumer applications [5].

The 3D-RS algorithm stimulates smoothness of the vector field by employing recursion. In this case the motion field $\vec{d}(t)$ is given by

$$\vec{d}(t) \ni \vec{d}(\vec{b}_c, t) = \left\{ \vec{C} \in CS(\vec{b}_c, t) \mid e(\vec{C}, \vec{b}_c, t) < e(\underline{V}, \vec{b}_c, t) \right\} \forall (\underline{V} \in CS(\vec{b}_c, t)),$$

$$CS^1(\bar{b}_c, t) = \begin{bmatrix} (\bar{d}^2(\bar{b}_c - \begin{pmatrix} X \\ Y \end{pmatrix}, t), \\ (\bar{d}^2(\bar{b}_c - \begin{pmatrix} -X \\ Y \end{pmatrix}, t), \\ (\bar{d}(\bar{b}_c - \begin{pmatrix} 0 \\ -2Y \end{pmatrix}, t - T)), \\ (\bar{d}^2(\bar{b}_c - \begin{pmatrix} X \\ 0 \end{pmatrix}, t) + \bar{U}_1, \\ (\bar{d}^2(\bar{b}_c - \begin{pmatrix} X \\ 0 \end{pmatrix}, t) + \bar{U}_2 \end{bmatrix} \quad (1)$$

$$U_{1 \times Y} = \text{random}(-a_1, \dots, a_1), U_{2 \times Y} = \text{random}(-a_2, \dots, a_2)$$

where $\text{random}(-a, \dots, a)$ denotes a random choice from the range $[-a, a]$.

The candidate set $CS(\bar{b}_c, t)$ consists of 5 vectors:

- three predictor vectors from a spatio-temporal neighborhood: two from directly adjacent blocks in the same field at the upper-left and upper-right corners of the present block, and one block from a previous field, not directly adjacent and located below and to the right of the present block, and
- two vectors obtained by adding a random update vector to the motion vector estimated for the previous block, i.e. the left neighbor.

This implicitly assumes spatial and/or temporal consistency. It is possible to use a half-pixel accuracy 3-D Recursive Search block-matcher is proposed, where $[-a_1, a_1] = [-1, 1]$ and $[-a_2, a_2] = [-6, 6]$.

The 3D-RS algorithm leads to very smooth vector fields. This fact reflects its improved coherency strategy (recursive search with spatial and temporal candidates). However, low bit-rate H.263 video coding leads to quite poor video quality. Moreover, dealing with CIF or QCIF formats, the number of 16×16 blocks is relatively small and that causes a slower convergence of the algorithm; these constraints seem to be too strong under certain circumstances, and that makes fall the motion estimator in local minimum errors.

If its low computational load (only five displacements are checked) is taken into account, the 3D-RS algorithm is an efficient motion estimator. [6] shows a comparison with the full-search motion estimator; for good quality images in the range of 32 to 37 dB PSNR, the average P-frame bit-rate increases with only some 5% to achieve the same PSNR.

However, in H.263 video coding context the performance of the 3D-RS algorithm is less satisfactory.

The Enhanced 3D-RS motion estimation algorithm.

The recursive strategy of the 3D-RS algorithm stimulates the smoothness of the motion field; this is an advantage because the more the smoothness is, the less the bits spent for motion data are (due to the entropy encoding of the motion information). However, the strong recursion of the 3D-RS algorithm may lead to local minimum errors, which impairs the efficiency of the resulting displacement-compensated image prediction. Anyway, we can regard the 3D-RS algorithm as a very efficient coarse motion estimator, whose estimated motion field needs refining.

To this end, the spatial recursion of the algorithm is exploited; if a one-pixel search window refinement around each motion vector at macro-block level is performed, the correction on the currently estimated motion vector is immediately forwarded to the estimation of the next displacement vector.

This solution is shown in Fig. 1. A current image I_n and a previous image I_{n-1} , random update vectors $U1$ and $U2$, and prediction vectors PV from a motion field memory MEM are applied to an estimation circuit E for generating the best vector $d^1(b,t)$ in the manner described above with regard to the 3D-RS algorithm. The integer pixel refinement block REF, inserted into the recursive loop of the estimator, enhances the convergence and speeds up the recursion of the algorithm. It processes the vector $d^1(b,t)$ from the estimation circuit E to obtain a vector $d^2(b,t)$. The vector $d^2(b,t)$ is stored in the motion field memory MEM that outputs the output vector $d(t)$. On formulas, the motion field $\vec{d}(t) \ni \vec{d}(\vec{b}_c, t) = \vec{d}^2(\vec{b}_c, t)$ is found as

$$\vec{d}^s(\vec{b}_c, t) = \left\{ \vec{C} \in CS^s(\vec{b}_c, t) \mid e(\vec{C}, \vec{b}_c, t) < e(\underline{V}, \vec{b}_c, t) \right\}$$

$$\forall (\underline{V} \in CS^s(\vec{b}_c, t)), s=1,2$$

$$CS^1(\vec{b}_c, t) = \left[\begin{array}{l} (\vec{d}^2(\vec{b}_c - \begin{pmatrix} X \\ Y \end{pmatrix}, t), \\ (\vec{d}^2(\vec{b}_c - \begin{pmatrix} -X \\ Y \end{pmatrix}, t), \\ (\vec{d}(\vec{b}_c - \begin{pmatrix} 0 \\ -2Y \end{pmatrix}, t - T)), \\ (\vec{d}^2(\vec{b}_c - \begin{pmatrix} X \\ 0 \end{pmatrix}, t), \\ (\vec{d}^2(\vec{b}_c - \begin{pmatrix} X \\ 0 \end{pmatrix}, t) + \vec{U} \end{array} \right] \quad (2)$$

$$\vec{U} = (\alpha_x, \alpha_y) \begin{pmatrix} R_x \\ R_y \end{pmatrix}, \vec{R} = \left[\vec{d}^2(\vec{b}_c - \begin{pmatrix} X \\ 0 \end{pmatrix}, t) - \vec{d}^1(\vec{b}_c - \begin{pmatrix} X \\ 0 \end{pmatrix}, t) \right]$$

$$5 \quad CS^2(\vec{b}_c, t) = \left\{ \vec{C} = \vec{d}^1(\vec{b}_c, t) \mid \vec{R} \right\} R_{x,y} = \{0, +1, -1\}$$

Herein, the superscript s refers to the step $s = 1..N$ in the computation of the motion field.

Equation (2) also shows that a different updating strategy suitable for enhanced estimation can be adopted. No random updates are added to the spatial predictor; this can be explained by the fact that the refinement process improves the accuracy of the motion estimate. Therefore, the displacement vector calculated for the previous block is supposed to be a more reliable predictor to ensure convergence to accurate motion field. In order to enable quick convergence, the update vector U is achieved multiplying ' R ' by the updating step a , where ' R ' is the refinement term related to the previously computed motion vector; in this way the updating process adapts to the local minimum direction. Experimental results proved that the proposed updating strategy leads to some performance improvement with respect to random strategy.

The total number of candidate vectors is 13. Note that, unlike iterative estimation, no additional delay is introduced; indeed, the displacement vectors are immediately available after processing each block.

This invention is not concerned with determining sets of candidate vectors. From a lot of experiments on candidate vectors, it followed that, as far as H.263 video coding

is concerned, one can hardly achieve better performance by simply modifying the set of candidate vectors of the 3D-RS algorithm.

Therefore, it is not proposed to use a particular set of candidate vectors. Any set of any version of the 3D-RS algorithm that can be found in the literature can be used. Also, the candidate vectors of spatially neighboring blocks can be used as candidate vectors, according to EP 0,415,491.

One of the important aspects of this invention is as follows. Since the 3D-RS algorithm for H.263 video coding provides quite inaccurate motion vectors, the purpose of the enhancement module is to improve the accuracy of the estimated motion field; thus, the enhancement can be regarded as a post processor of motion vectors. As the enhancement is a post-processing module, it is not involved in determining the set of candidate vectors, as it processes the motion vector associated with the present block, once the best displacement has been selected out of the candidate vectors. Usually, post-processing is done once the whole motion field has been computed.

A new aspect of the enhancement of this invention is that better results can be achieved by doing post processing inside the recursion loop of the motion estimation algorithm, provided that the motion field is computed by a recursive motion estimation algorithm. This means that once the motion vector V0 has been selected out of the candidate vectors, said motion vector V0 is refined to produce the motion vector V1, in that if the frame difference corresponding to V1 is smaller than the frame difference associated with V0, V1 immediately replaces V0 before the new set of candidate vectors for the next block is generated.

Note that this technique may be used for any recursive motion estimation algorithm; it can be also used for the motion estimation algorithm described in US 4,853,775.

The post processing of a preferred embodiment of this invention includes an integer pixel refinement around the motion vector that has been selected by the motion estimator; however, any refinement technique able to achieve more accurate motion field may be used. Very good results can be obtained if within the recursion loop, the integer pixel refinement is followed by a half pixel refinement; this solution results, however, in a relatively large computational load, so that the integer pixel refinement is preferred.

The new and important aspect is that, provided that post processing is done inside the recursion loop of any recursive motion estimation algorithm instead of outside the recursion loop, the convergence of the recursive motion estimation algorithm is speeded up.

Another important aspect of a preferred embodiment of this invention is that the difference between the output and the input of the enhancement module gives a local information on the trend of the motion (see Equation 2). This information can be exploited to determine an additional candidate vector which contributes to further improve the performance of the algorithm (see also attached block diagram). This can be regarded as an optional feature of the proposed scheme, meaning that the enhancement provides itself conspicuous performance gain, even if the above defined additional candidate vector is not added to the original candidate set.

It is noted that both simulation results and subjective tests have confirmed the effectiveness of the enhancement; a lot of time have been spent finding an efficient technique to improve the performance of the 3D-RS algorithm, which provides poor rate-distortion performance when used for H.263 video coding purpose. Although many optimization steps were done to tune various parameters of the 3D-RS algorithm and various techniques to refine the motion field estimated by the 3D-RS algorithm were evaluated, only the adoption of the enhancement scheme described above resulted in considerable performance gain.

The Enhanced 3D-RS motion estimation algorithm for H.263 video coding application provides a satisfactory performance in terms of coding efficiency while keeping low the computational load. The Enhanced 3D-RS algorithm outperforms the improved iterative 3D-RS strategy, and in case of typical video-conferencing sequences it is very close to full-search motion estimation. Furthermore, the recursive estimation strategy stimulates better consistency of the motion field and leads to improved noise robustness of the motion estimation process, in that the Enhanced 3D-RS is comparable with full-search in case of noisy sequences.

The Enhanced 3D-RS algorithm has been successfully integrated with the H.263 video codec for the Philips Trimedia processor (TM1000). It has been seen that this motion estimation algorithm leads to significant computational saving, and real-time experiments have proved very good perceptual quality of the coded sequences.

The drawing shows a block diagram of an enhanced three-dimensional recursive search circuit in accordance with the present invention. Images I_n and I_{n-1} are applied to a motion estimator E, to which also a plurality of prediction vectors PV from a memory MEM and two update vectors U1 and U2 are applied. A selected output vector $d^1(b,t)$ of the

estimator E is applied to a refinement circuit REF that furnishes an output vector $d^2(b, t)$ to the memory MEM that furnishes the output vector $d(t)$.

The invention thus discloses a method and an apparatus of improving the accuracy of the motion field estimated by a motion estimation algorithm, which allows improved convergence of the motion estimation algorithm with respect to conventional methods, provided that the motion field is estimated by a recursive motion estimation algorithm. The word recursive means that the motion estimation algorithm computes the motion vector associated with a picture portion (for example a block) by exploiting motion information already determined for previous blocks.

Preferably, eight motion vectors are generated from the motion vector V_0 that has been selected out of the corresponding candidate vector set. This apparatus is called enhancement module.

Preferably, each of the eight vectors is achieved by adding ± 1 pixel displacement to each component of the motion vector V_0 that has been selected out of the candidate vector set. The motion vector V_1 out of said eight motion vectors with the smallest frame difference is selected. If the frame difference of said motion vector V_1 is smaller than the frame difference of the motion vector V_0 , the motion vector V_1 immediately replaces the motion vector V_0 before the new set of candidate vectors for the motion vector associated with the next block is generated.

Preferably, a local information is provided on the trend of the motion by computing an update vector given by the difference between output and input of the enhancement. This update vector can be used to generate one more candidate vector by adding the update vector to one of the vectors of the candidate vector set.

Advantageously, the convergence of the 3D-RS motion estimation algorithm is speeded up to obtain a more accurate motion field. Advantageously, the method allows substantial rate-distortion performance gain when applied to H.263 video coding, as well as improved subjective quality.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of other elements or steps than those listed

in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means can be embodied by one and the same item of hardware.

References:

- [1] ITU-T DRAFT Recommendation H.263, Video coding for low bit-rate communication, 2 May 1996.
- [2] K. Rijkse, "ITU standardisation of very low bit-rate video coding algorithms", *Signal Processing: Image Communication* 7 (1995) pp. 553-565.
- [3] G. de Haan, P.W.A.C. Biezen, H. Huijgen, O.A. Ojo, "True motion estimation with 3-D recursive search block matching", *IEEE Trans. Circuits and Systems for Video Technology*, Vol. 3, October 1993, pp. 368-379.
- [4] G. de Haan, P.W.A.C. Biezen, "Sub-pixel motion estimation with 3-D recursive search block-matching", *Signal Processing: Image Communication* 6 (1995), pp. 485-498.
- [5] P. Lippens, B. De Loore, G. de Haan, P. Eeckhout, H. Huijgen, A. Loning, B. McSweeney, M. Verstraelen, B. Pham, J. Kettenis, "A video signal processor for motion-compensated field-rate upconversion in consumer television", *IEEE Journal of Solid-state Circuits*, Vol. 31, no. 11, November 1996, pp. 1762-1769.
- [6] W. Bruls, A. van der Werf, R. Kleihorst, T. Friedrich, E. Salomons, F. Jorritsma, "A single-chip MPEG2 encoder for consumer video storage applications", ICCE '97, 1997.

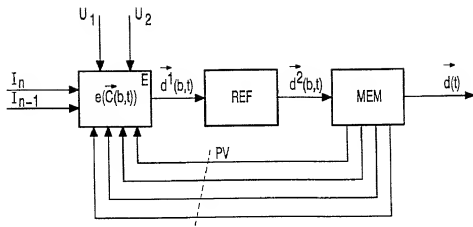
CLAIMS:

1. A recursive motion vector estimation method, comprising the steps of:
generating (E) a plurality of candidate vectors from stored vectors (PV);
selecting (E) one of these candidate vectors to generate a selected vector (d^1);
generating (REF) a plurality of test vectors from the selected vector (d^1);
5 selecting (REF) one of the test vectors to generate an output vector (d^2); and
storing (MEM) the output vector (d^2).
2. A method as claimed in claim 1, wherein said step of generating a plurality of
test vectors from the selected vector (d^1) includes the step of adding -1 , 0 , or $+1$ to each
10 component of the selected vector (d^1).
3. A device for recursive motion vector estimation, the device comprising:
means (E) for generating a plurality of candidate vectors from stored vectors;
means (E) for selecting one of these candidate vectors to generate a selected
15 vector (d^1);
means (REF) for generating a plurality of test vectors from the selected vector
(d^1);
means (REF) for selecting one of the test vectors to generate an output vector
(d^2); and
20 means (MEM) for storing the output vector (d^2).

ABSTRACT:

In a method of recursive motion vector estimation, a plurality of candidate vectors is generated (E) from stored vectors (PV), one of these candidate vectors is selected (E) to generate a selected vector (d^1), a plurality of test vectors is generated (REF) from the selected vector (d^1), one of the test vectors is selected (REF) to generate an output vector (d^2),
5 and the output vector (d^2) is stored (MEM).

Fig. 1



DECLARATION and POWER OF ATTORNEY

ATTORNEY'S DOCKET NO.:

PHN 17.446

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

"Motion vector estimation"

the specification of which (check one)

☐ is attached hereto.

☐ was filed on _____ as Application Serial No. _____ and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by the amendment(s) referred to above.

I acknowledge the duty to disclose information which is material to patentability of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

PRIOR FOREIGN APPLICATION(S)

COUNTRY	APP. NUMBER	DATE OF FILING (DATE, MONTH, YEAR)	PRIORITY CLAIMED UNDER 35 U.S.C. 119
Europe	98204149.3	7 December 1998	YES
Europe	99201556.0	18 May 1999	YES

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35 United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

PRIOR UNITED STATES APPLICATION(S)

APPLICATION SERIAL NUMBER	FILING DATE	STATUS (PATENTED, PENDING, ABANDONED)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (list name and registration number)

Algy Tamoshunas, Reg. No. 27,677

Jack E. Haken, Reg. No. 26,902

SEND CORRESPONDENCE TO: Corporate Patent Counsel; U.S. Philips Corporation; 580 white Plains Road; Tarrytown, NY 10591	DIRECT TELEPHONE CALLS TO: (name and telephone No.) (914) 332-0222
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Dated:		Inventor's Signature:		
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